DIO8352
High Frequency & High Performance Off-line Quasi-Resonant Flyback Controller

Features

- Built-in HV startup circuit
- Valley-lockout for noise-free operation
- Rapid frequency foldback at light load
- Skip mode during light loads
- Internal frequency jittering
- Adjustable maximum frequency clamp
- Full reliable protection:
  - Overcurrent protection (OCP)
  - Overload protection (OLP)
  - Overvoltage protection (OVP)
  - Adjustable overpower protection (OPP)
  - Short circuit protection (SCP)
  - Overtemperature shutdown (OTP)
  - NTC compatible for OTP
- Brown in/out protection
- Soft start timer: 4 ms
- SSOP10 package

Descriptions

The DIO8352 is a quasi-resonant flyback controller which provides high-performance voltage regulation using an optically coupled feedback signal from a secondary-side voltage regulator, targeting at off-line PD Constant Voltage (CV) power converters applications.

With HV startup circuit, the DIO8352 can enable low standby power consumption.

Proprietary valley lockout circuitry is optimized for stable valley switching. As the load decreases further, the DIO8352 enters quiet mode to regulate the power delivery, then minimizing acoustic noise.

This chip adopts special design to achieve quick start up and reliable protection for safety requirement.

Applications

- USB PD adapter and charger
- AC/DC power supply
- Standby supply for LCD TV and desktop

Ordering Information

Ordering Part No.	Top Marking	MSL	RoHS	T_A	Package	
DIO8352SS10	DIOHC5B	3	Green	-40 to 85°C	SSOP-10	Tape & Reel, 3000

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Pin Assignment

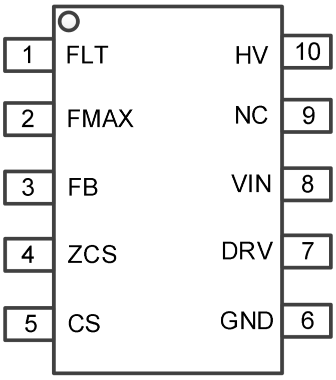

Figure 1. SSOP10 (Top view)

Pin Descriptions

Pin Name	Description
FLT	The controller enters FLT mode if the voltage on this pin is pulled above or below the FLT thresholds. A precise pull up current source allows direct interface with an NTC thermistor.
FMAX	A resistor to ground sets the value for the maximum switching frequency clamp. If this pin is pulled above 4 V, the maximum frequency clamp is disabled.
FB	Feedback input for the QR Flyback controller. Allows direct connection to an optocoupler.
ZCS	A resistor divider from the auxiliary winding to this pin provides input to the demagnetization detection comparator and sets the OPP compensation level.
CS	Input to the cycle-by-cycle current limit comparator.
GND	Ground reference.
DRV	This is the drive pin of the circuit. The DRV high−current capability (−0.5 /+0.8 A) makes it suitable to effectively drive high gate charge power MOSFETs.
VIN	This pin is the positive supply of the IC. The circuit starts to operate when VIN exceeds 16 V and turns off when VIN goes below 8 V (typical values). After start−up, the operating range is 9.5 V up to 34 V.
NC	Removed for creepage distance.
HV	This pin is the input for the high voltage startup and brownout detection circuits.

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Absolute Maximum Ratings

Stresses beyond those listed under the Absolute Maximum Rating table may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other condition beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Symbol	Parameter	Rating	Unit
V_{HV}	HV	700	V
$V_{FLT, ZCS, VIN}$	FLT, ZCS, VIN	40	V
V_{DRV}	DRV	14	V
$V_{FMAX, FB, CS}$	FMAX, FB, CS	5.5	V
P_D	Power dissipation at T_A = 25°C	330	mW
θ_{JA}	Package thermal resistance[1]	130	°C/W
θ_{JC}		80	
T_J	Junction temperature range	-40 to 150	°C
T_L	Lead temperature	260	°C
T_{STG}	Storage temperature range	-65 to 150	°C

Note:

(1) Measured on JESD51-7, 4-layer PCB.

Recommend Operating Conditions

Recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. DIOO does not recommend exceeding them or designing to absolute maximum ratings.

Symbol	Parameter	Rating	Unit
	Supply voltage	9.5 to 34	V
T_J	Junction temperature range	-40 to 125	°C
T_A	Ambient temperature range	-40 to 85	°C

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Electrical Characteristics

VIN = 12 V, V_{HV} = 120 V, V_{FLT} = open, V_{FB} = 2.4 V, V_{CS} = 0 V, V_{ZCS} = 0 V, V_{FMAX} = 0 V, C_{VIN} = 100 nF, C_{DRV} = 100 pF, for typical values T_J = 25°C, for min/max values, T_J is -40°C to 125°C, unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Start-up and supply circuits						
V_{VIN_ON}	Startup threshold	dV/dt = 0.1 V/ms, VIN increasing		16		V
V_{VIN_OFF}	Minimum operating voltage	dV/dt = 0.1 V/ms, VIN decreasing		8		V
I_{ST1}	Inhibit current sourced from VIN pin	VIN = 0 V		0.5		mA
I_{ST2}	Start-up current sourced from VIN pin	VIN = V_{VIN_ON} - 0.5 V		3.6		mA
I_{HV_OFF}	Start-up circuit off-state leakage current	V_{HV} = 500 V			50	µA
I_{CC}	Operating current	f_{SW} = 50 kHz, C_{DRV} = open		1		mA
V_{VIN_OVP}	VIN overvoltage protection threshold			36		V
Brownout detection						
V_{BO_DIS}	System start-up threshold	V_{HV} increasing		94		V
V_{BO_EN}	Brownout threshold	V_{HV} decreasing		84		V
t_{BO_EN}	Brownout detection blanking time	V_{HV} decreasing		70		ms
Gate drive						
t_{DRV_R}	Rise time	C_{DRV} = 1 nF		80		ns
t_{DRV_F}	Fall time	C_{DRV} = 1 nF		35		ns
V_{DRV_H}	High state voltage	VIN = 30 V, R_{DRV} = 10 kΩ		12	14	V
V_{DRV_L}	Low state voltage	V_{FLT} = 0 V			0.25	V
Feedback						
K_{FB}	Gain			4		
R_{FB}	Internal pull-up resistor	V_{FB} = 0.4 V		20		kΩ
f_{MAX1}	Maximum frequency clamp	V_{FMAX} = 0.5 V		500		kHz
V_{FMAX_DIS}	FMAX disable threshold			4		V
I_{FMAX}	FMAX pin source current			10		µA
t_{ON_MAX}	Maximum on time			32		µs
Demagnetization input						
V_{ZCS_TRIG}	ZCS threshold voltage	V_{ZCS} decreasing		60		mV
V_{ZCS_HYS}	ZCS hysteresis	V_{ZCS} increasing		25		mV
t_{ZCS_BLANK}	Blanking delay after turn-off			700		ns
$t_{TIMEOUT1}$	Timeout after last demagnetization detection	While in soft-start		100		µs

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$t_{TIMEOUT2}$	Timeout after last demagnetization detection	After soft-start complete		6.0		μs
Current sense						
V_{ILIM1}	Current limit threshold voltage	V_{CS} increasing	0.72	0.8	0.88	V
t_{LEB1}	Leading edge blanking duration	DRV minimum width minus $t_{delay(ILIM1)}$		265		ns
Current sense						
V_{CS_MIN}	Minimum peak current			100		mV
V_{ILIM2}	Abnormal overcurrent FLT threshold	V_{CS} increasing, V_{FB} = 4 V	1.08	1.2	1.32	V
t_{LEB2}	Abnormal overcurrent FLT blanking duration	DRV minimum width minus $t_{delay(ILIM2)}$		110		ns
FLT protection						
t_{SS}	Soft-start time			4.0		ms
t_{OVLD}	OLP time	$V_{CS} = V_{ILIM1}$		160		ms
V_{FLT_OVP}	Overvoltage protection threshold	V_{FLT} increasing		3		V
$V_{FLT\_OTP\_in}$	Overtemperature protection threshold (1)	V_{FLT} decreasing		400		mV
$V_{FLT\_OTP\_OUT}$	Overtemperature protection (OTP) exiting threshold(1)	V_{FLT} increasing		910		mV
I_{OTP}	OTP pull-up current source	$V_{FLT} = V_{FLT(OTP\_in)}$ + 0.2 V T_J = 25°C to 125°C		45		uA
V_{FLT_CLAMP}	FLT input clamp voltage			1.7		V
Light / No load management						
f_{MIN}	Minimum frequency clamp		21.5	25		kHz
t_{DT_MAX}	Dead-time added during frequency foldback	V_{FB} = 400 mV	32			μs
V_{SKIP}	Skip threshold	V_{FB} decreasing		400		mV
V_{SKIP_HYS}	Skip hysteresis	V_{FB} increasing		50		mV
Rapid frequency foldback						
ΔV_{CS_RFF}	Minimum peak current shift			250		mV
$V_{CS\_RFF\_EN}$	Entry threshold			800		mV
$V_{CS\_RFF\_EX}$	Exit threshold			750		mV
Thermal protection						
T_{SD}	Thermal shutdown	Temperature increasing		140		°C
T_{SD_HYS}	Thermal shutdown hysteresis	Temperature decreasing		40		°C

Note:

(1) NTC with 8.8 kΩ thermistor.

(2) Specifications subject to change without notice.

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Typical Characteristics

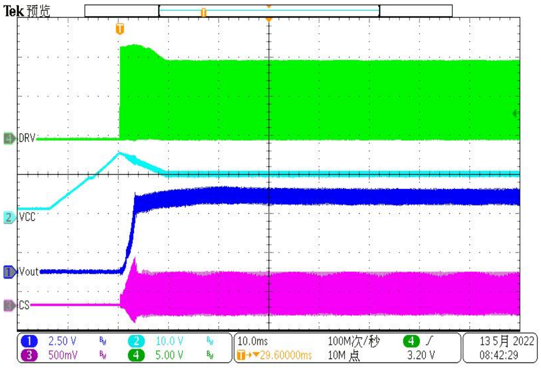


Figure 2. Full load power ON at 90 V$_{AC}$

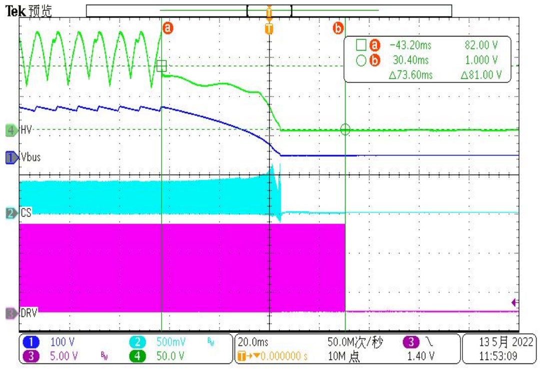
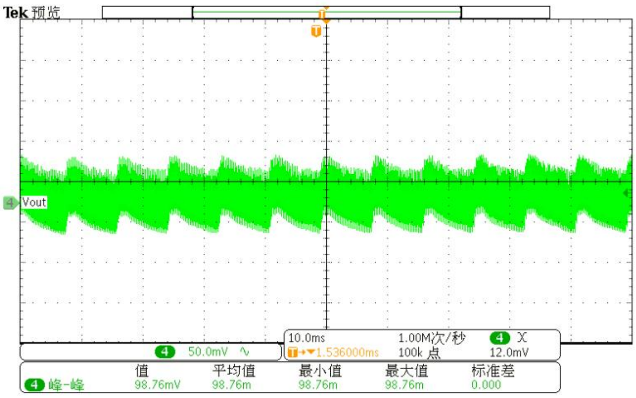
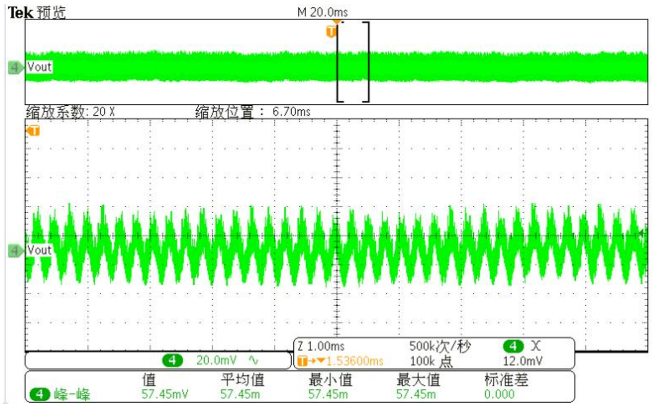


Figure 3. Full load power OFF at 90 V$_{AC}$



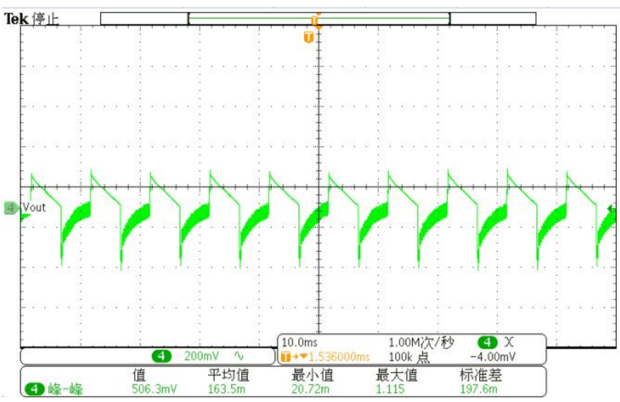
20 V / 3.25 A at 115 V$_{AC}$

Figure 4. Ripple



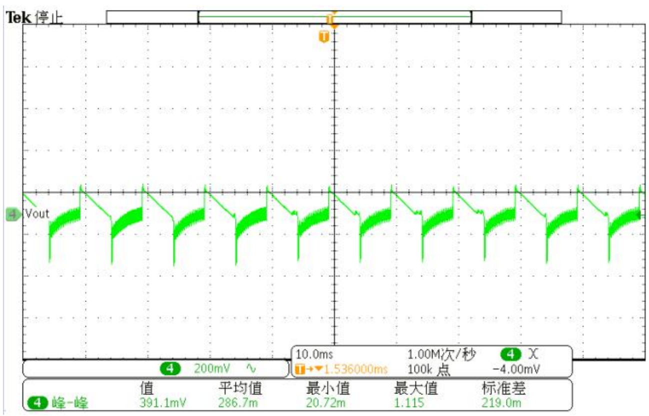
20 V / 3.25 A at 230 V$_{AC}$

Figure 5. Ripple



V$_{OUT}$ = 20 V, V$_{AC}$ = 115 V$_{AC}$

Figure 6. Load transient response



V$_{OUT}$ = 20 V, V$_{AC}$ = 230 V$_{AC}$

Figure 7. Load transient response

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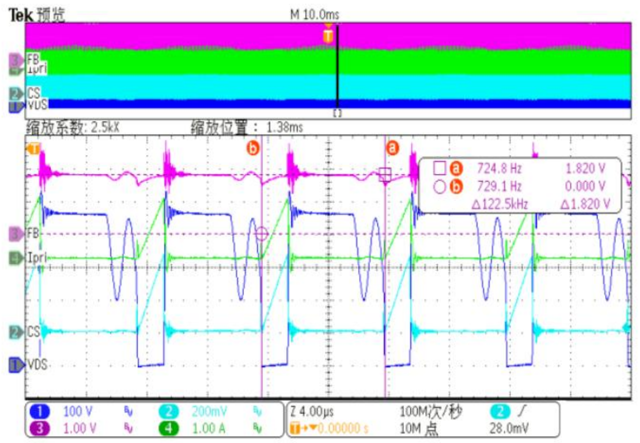
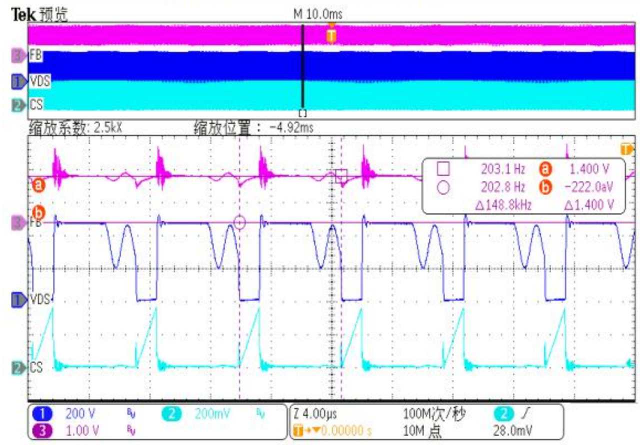
CH1:V_{DS}, CH2:V_{CS}, CH3:V_{FB}, CH4:Ipri



V_{IN} = 230 V_{AC}, I_O = 3.25 A

Figure 8. 100% Load operation

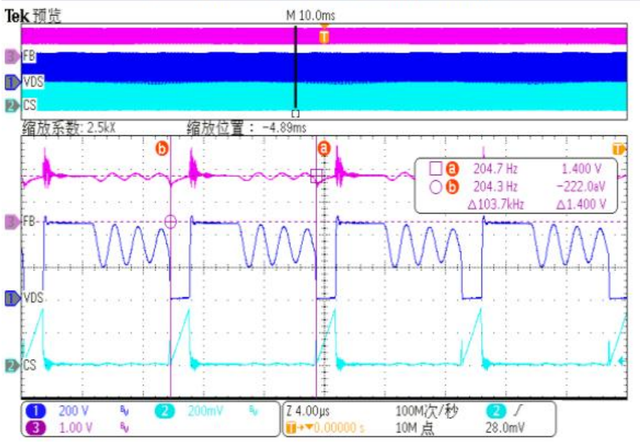
CH1:V_{DS}, CH2:V_{CS}, CH3:V_{FB}, CH4:Ipri



V_{IN} = 230 V_{AC}, I_O = 2.44 A

Figure 9. 75% Load operation

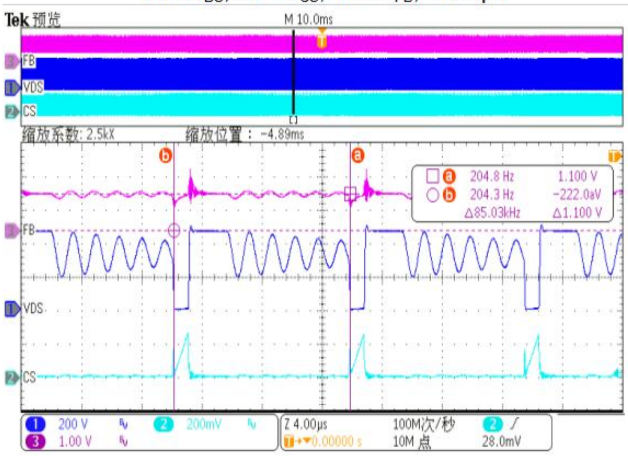
CH1:V_{DS}, CH2:V_{CS}, CH3:V_{FB}, CH4:Ipri



V_{IN} = 230 V_{AC}, I_O = 1.63 A

Figure 10. 50% Load operation

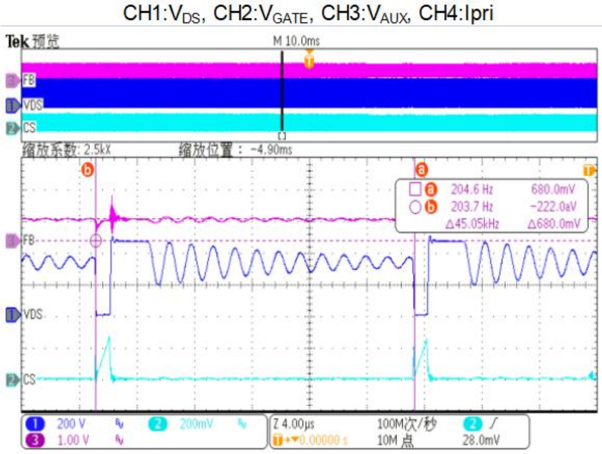
CH1:V_{DS}, CH2:V_{CS}, CH3:V_{FB}, CH4:Ipri



V_{IN} = 230 V_{AC}, I_O = 0.81 A

Figure 11. 25% Load operation

CH1:V_{DS}, CH2:V_{GATE}, CH3:V_{AUX}, CH4:Ipri



V_{IN} = 230 V_{AC}, I_O = 0.325 A

Figure 12. 10% Load operation

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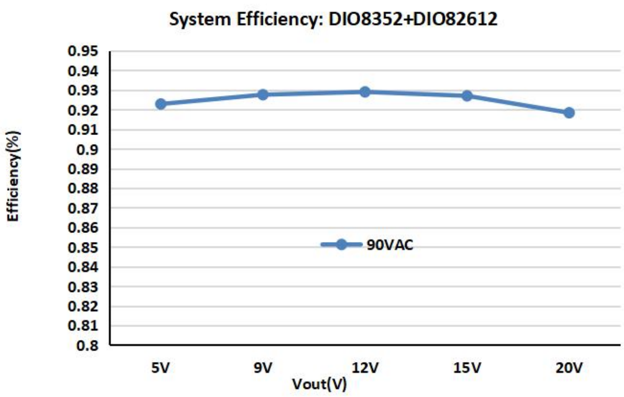

Figure 13. Efficiency vs. V_{OUT} (90 V_{AC})

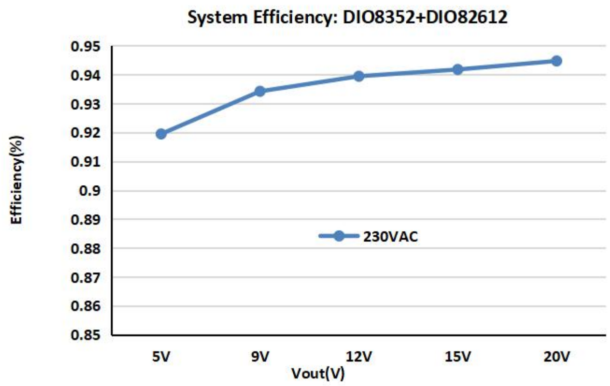

Figure 14. Efficiency vs. V_{OUT} (230 V_{AC})

Block Diagram

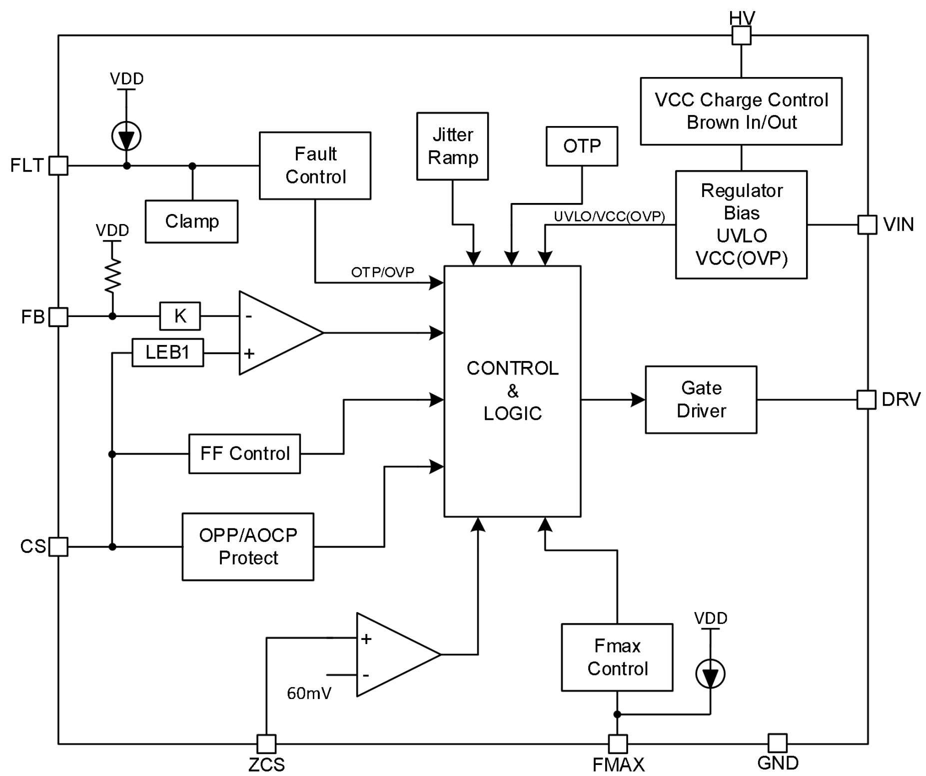

Figure 15. Block diagram

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Typical Applications

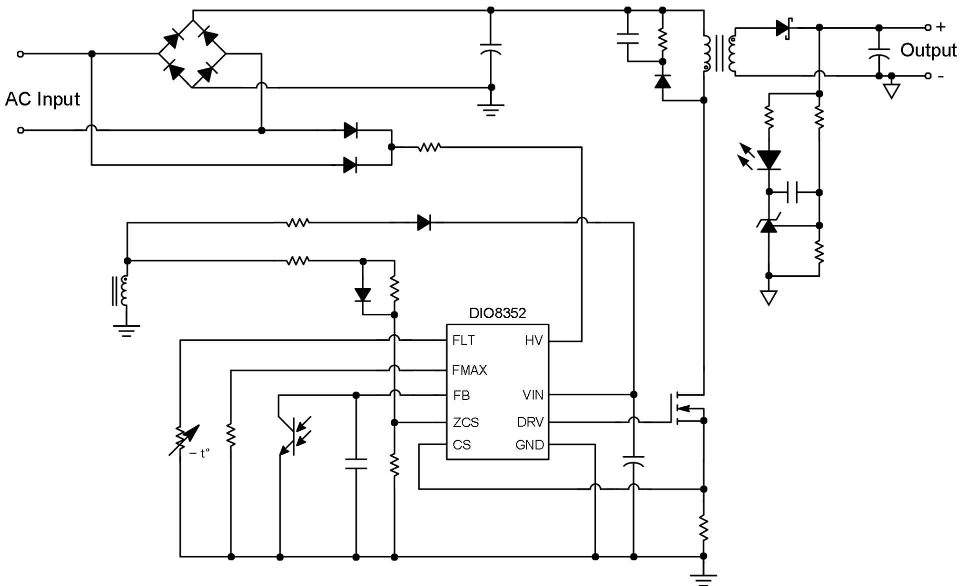

Figure 16. Typical application circuit

Detailed Description

The DIO8352 is a quasi−resonant flyback power-supply controller which provides high-performance voltage regulation using an optically coupled feedback signal from a secondary-side voltage regulator. The DIO8352 is an ideal candidate where low parts count and cost effectiveness are the key parameters, particularly in AC-DC adapters, etc. The DIO8352 integrates all the necessary components normally needed in modern power supply designs, bringing several enhancements such as non-dissipative overpower protection (OPP), brownout protection, external OTP, and frequency reduction management for optimized efficiency over the entire power range. Accounting for the needs of extremely low standby power requirements, the controller has minimized current consumption.

High voltage startup circuit

An internal high-voltage startup switch, connected to the bulk-capacitor voltage (V_{BULK}) through the HV pin, charges the VIN capacitor. Low standby power consumption cannot be obtained with the classic resistive startup circuit. The DIO8352 incorporates a high voltage current source to provide the necessary current during startup and then turns off during normal operation.

Internal brownout protection

The AC input voltage is sensed via the high-voltage pin. When this voltage is too low, the DIO8352 stops switching. No restart attempt is made until the AC input voltage is back within its normal range.

Quasi-resonant, current-mode operation

The quasi-resonant (QR) mode is an efficient mode of operation where the MOSFET turn−on is synchronized with the point where its drain−source voltage is at the minimum. A drawback of this mode of operation is that the operating frequency is inversely proportional to the system load. The DIO8352 uses valley locking and frequency folding techniques to eliminate this drawback, thus maximizing the efficiency over the entire power range.

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Valley lockout

In order to limit the maximum frequency while remaining in QR mode, one would traditionally use a frequency clamp. Unfortunately, this can cause the controller to jump back and forth between two different valleys, which is often undesirable. The DIO8352 patented valley locking circuitry solves this issue by determining the operating valley based on the system load, and locking out other valleys unless a significant change in load occurs.

Rapid frequency foldback

Reduce the switch frequency as the load continues to drop. When the load is sufficiently light, the DIO8352 enters a rapid frequency foldback mode. During the rapid frequency foldback mode, the minimum peak current is limited and the dead time is increased during the switching cycle, thus reducing the frequency and switching operations to the discontinuous conduction mode (DCM). Continue to add dead time until skip mode is reached, or the switching frequency reaches its lowest level of 25 kHz.

Limited peak current modulation (LPCM)

In order to reduce the switching frequency even faster (for high frequency designs), the DIO8352 uses LPCM to increase the minimum peak current during frequency foldback. It also reduces the minimum peak current gradually as the load decreases to ensure optimum skip mode entry.

Skip mode

To further decrease the light or no-load power consumption, while avoiding audible noise, the DIO8352 enters the skip mode when the operating frequency reaches its minimum value. To avoid acoustic noise, the circuit can prevent a switching frequency attenuation below 25 kHz.This allows modulation by pulse bursts at 25 kHz or higher rather than working within the audible range.

Quiet-skip

To further reduce acoustic noise, the DIO8352 provides a novel circuit to prevent the skip mode burst period from entering the audible range as well.

Internal OPP

To limit power delivery on the high line, a proportional version of the negative voltage present on the auxiliary winding during the on time is sent to the ZCS pin. This provides a simple non-dissipative method to reduce maximum power capability with increasing bulk voltage.

Frequency jittering

The DIO8352 provides a frequency jittering function, which simplifies the input EMI filter design and decreases system cost. The DIO8352 has optimized frequency jittering with 4 kHz carrier cycle that improves EMI effectively by spreading out the energy peaks during noise analysis.

Internal soft-start

In the process of start up, the current of drain increases to maximum limitation step by step. As a result, it can reduce the stress of secondary diode greatly and prevent the transformer turning into the saturation states. Typically, the duration of soft-start is 4 ms.

Dedicated FLT input

The DIO8352 includes a dedicated FLT input. It can be used to sense an overvoltage condition by pulling the pin above the overvoltage protection (OVP) threshold. The controller is also disabled if the FLT pin is pulled below the overtemperature protection (OTP) threshold. The OTP threshold is configured for use with an external NTC thermistor.

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Overload/short-circuit protection

The DIO8352 implements overload protection by limiting the maximum time duration for operation during overload conditions. The overload timer operates whenever the maximum peak current is reached. In addition to this, special circuitry is included to prevent operation in CCM during extreme overloads, such as an output short-circuit.

Maximum frequency clamp

The DIO8352 includes a maximum frequency clamp. The clamp can be adjusted via an external resistor from the FMAX Pin to ground. It can also be disabled by pulling the FMAX pin above 4 V.

Thermal shutdown

An internal thermal shutdown circuit monitors the junction temperature of the controller. If the junction temperature exceeds the thermal shutdown threshold T_{SD} (typically 140°C), OTP fault is activated. Then the controller is shutdown. The controller restarts at the next V_{VIN_ON} once the junction temperature drops below T_{SD} by the thermal shutdown hysteresis, T_{SD_HYS}, typically 40°C.

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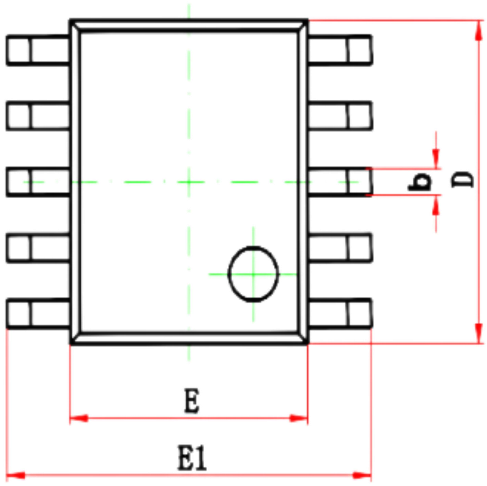
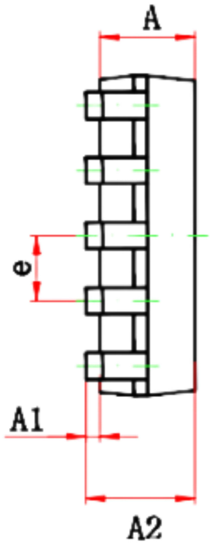
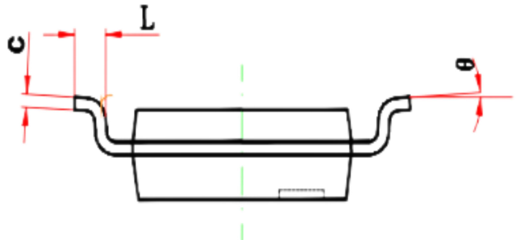
Physical Dimensions: SSOP10







Common Dimensions (Units of measure = Millimeter)			
Symbol	Min	Nom	Max
A	1.35	1.45	1.55
A1	0.00	0.04	0.08
A2	1.35	1.49	1.63
b	0.325	0.35	0.375
c	0.18	0.20	0.22
D	4.70	4.90	5.10
E	3.80	3.90	4.00
E1	5.80	6.00	6.20
e	1.00 BSC		
L	0.40	0.60	0.80
θ	0°	-	8°

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